Isolated deciduous woodlands in central Texas

Oscar W. Van Auken
Department of Integrative Biology
University of Texas at San Antonio
One UTSA Circle, San Antonio, TX 78249, USA
oscar.vanauken@utsa.edu

Donna L. Taylor
Cisebsi Ltd. Co.
Fair Oaks Ranch, Texas, 78015, USA

Janis K. Bush
Department of Integrative Biology
University of Texas at San Antonio
One UTSA Circle, San Antonio, TX 78249, USA

and

Jason R. Singhurst
Texas Parks and Wildlife Department
Texas State Government
4200 Smith School Road, Austin, TX 78744, USA

ABSTRACT

The Edwards Plateau of central Texas is a physiographic region mostly in private ownership that includes grasslands, savannas, woodlands, and forests. Isolated deciduous woodlands on steep hillsides and deep limestone canyons contain populations of bigtooth maple (*Acer grandidentatum*, Aceraceae). We completed an aerial survey when leaves were changing colors in the fall to identify bigtooth maple populations. We used the quadrat procedure to estimate the density and basal area of trees and the density of juveniles. We found sixteen tree species in the overstory. Mean overstory density and basal area were 559 plants/ha and 33.4 m^2/ha, respectively. In sequence Ashe juniper (*Juniperus ashei*) and bigtooth maple had the highest densities and were in the overstory of every community. Mean relative basal areas of these species were 5% and 43%, respectively, indicating the small size of Ashe juniper. We documented thirty understory woody species, and the mean density was 7,966 plants/ha. Sugar hackberry (*Celtis laevigata*) had the highest understory density, followed by Texas red oak (*Quercus buckleyi*), lacey oak (Q. *laceyi*), Ashe juniper, chinkapin oak (*Q. muehlenbergii*) and bigtooth maple. Juveniles of other species were scattered in various communities with high variation. Aerial photography and drone flights were very helpful finding these deciduous woodlands in part of this large physiographic region. *Published online **www.phytologia.org** Phytologia 104(3): 13-23 (September 20, 2022). ISSN 030319430.*

KEY WORDS: bigtooth maple, community composition, conservation, Edwards Plateau, herbivory, juniper, structure

---

Plants, plant community types, and animals were reported in logs kept by some travelers and Mexican soldiers during expeditions through south and central Texas from 1675–1691 (see Inglis 1964). They described some of the vegetation using common names and made comments about fires stretching across the grasslands. While descriptions indicated tree-covered hills to the west and northwest, the edge of the central Texas Edwards Plateau region, the historical records of this time do not describe the diverse composition of species on the steep limestone hills or canyons of this area (Hill 1892). Early travelers did not traverse this central Texas region.

Much later, Palmer (1920) reported the diverse flora of these central Texas Canyon plant communities. Many publications incorrectly considered Texas a grassland (Sims 1988; Barbour and Billings 1988), which was true at times in the past but is not true today. Plant communities today include mixed juniper-oak (*Juniperus-Quercus*) woodlands, mesquite (*Prosopis*) woodlands, scrublands, savannas, grasslands, as well as riparian communities (Van Auken et al. 1979; Van Auken 1988, 2000; Elliott et al. 2014; Van Auken and Ford 2017; Van Auken 2018). Many studies more generally covered the plant species present in the broad area of central Texas but not the deciduous communities found in the steep-sided, narrow canyons (Tharp 1939; Gould 1969; Correll and Johnston 1979). Many of the central Texas plant communities have been studied more carefully recently (Van Auken et al. 1981; Amos and Gehlback 1988; Gehlback 1988; Van Auken and Ford, 2017; Van Auken 2018), but there are many unstudied species in these areas, and the extent of the communities are not well known, even today.

In addition to these plant communities changing with the retreat of glaciers and warming during the late Pleistocene or early Holocene, 12,000 to 15,000 years ago, community changes accelerated with the arrival of the European settlers and their animals starting about 400 years ago but increased dramatically in the past 100-200 years. Most grasslands changed dramatically but the woodlands did not change so much. The causes of the most recent grassland changes are debated. However, they include climate change, chronic high levels of herbivory, change in fire frequency and intensity, changes in species competitive ability, the spread of seed by livestock, small mammal populations, elevated levels of CO_2, or a combination of these factors (Van Auken 2000). The most accepted causes of the grassland changes seem to be the dramatic increase in domestic animals leading to heavy and continuous overgrazing, which influences wildfire frequency and intensity in central and western North American grasslands and prairies, including those in Texas (Collins and Wallace 1990). The product is the encroachment and spread of woody plants and the increase of woodland communities and their cover. There are still many grasslands in the Edwards Plateau region, especially in the western part, but there are many shrubs present in these communities. Changes in the central Texas woodlands is not as well studied.

Little ecological or population information is available concerning the species in these central Texas woodland communities (Van Auken 2018). Changes occurring in the last 100 years in these woodlands and savannas are not caused by lack of plant reproduction, seed maturation, or seedling emergence, which have not changed since the arrival of the European settlers (Collins and Wallace 1990). Recruitment failure seems to be caused by post-germination factors. Anecdotal reports suggest that the density of some woodland species is declining, possibly caused by browsing of white-tailed deer (*Odocoileus virginianus* Zimmerman) (McCorkle 2007). This will cause preferred plants to decrease in density and those resistant to herbivory will increase in density (Strole and Anderson 1992; Ruzicka et al. 2010).

Before recruitment success can be measured, the structure of the deciduous communities, both overstory and understory, must be known. We designed this study to answer the following research questions. Where do deciduous communities with high densities of bigtooth maple occur in central Texas? What is the overstory and understory composition and structure of these communities? Our study documents the species present, community composition, and maps the occurrence of some of these woodlands. We hypothesize that bigtooth maples occur in steep canyons which provide some reduction in temperatures. We hypothesize that bigtooth maple may be a preferred browse species for herbivores in this area, and therefore may be decreasing in density. We hypothesize that recruitment success of the other species present may be related to their palatability or nutritional value.

MATERIALS AND METHODS

Study Area

Viewing some deciduous communities with bigtooth maple (*Acer grandidentatum* Nutt.) in Texas is probably best in the Lost Maples State Natural Area, located in the southeastern part of the Edwards Plateau. However, similar canyons exist on private properties with deciduous woodlands and bigtooth maple that have not been documented (Carpenter and Brandimarte 2014). The current study was within the Edwards Plateau physiographic region of Central Texas on steep limestone hills and in deep canyons (Fig. 1).

The Edwards Plateau is a physiographic region described by geomorphology and is approximately 93,000 km^2. This diverse physiographic region includes woodlands, scrublands, savannas, grasslands and riparian communities and many rare and endemic species (Amos and Gehlbach 1988; Poole et al. 2007; Van Auken 2018). We studied eight deciduous woodlands, similar to those previously described (Van Auken et al. 1981), but having bigtooth maple. The herbaceous species in these communities were previously identified (Palmer 1920). The current study focuses on bigtooth maple populations within these unusual deciduous woodland communities. However, all trees and shrubs as well as juveniles of all woody species were identified and counted.

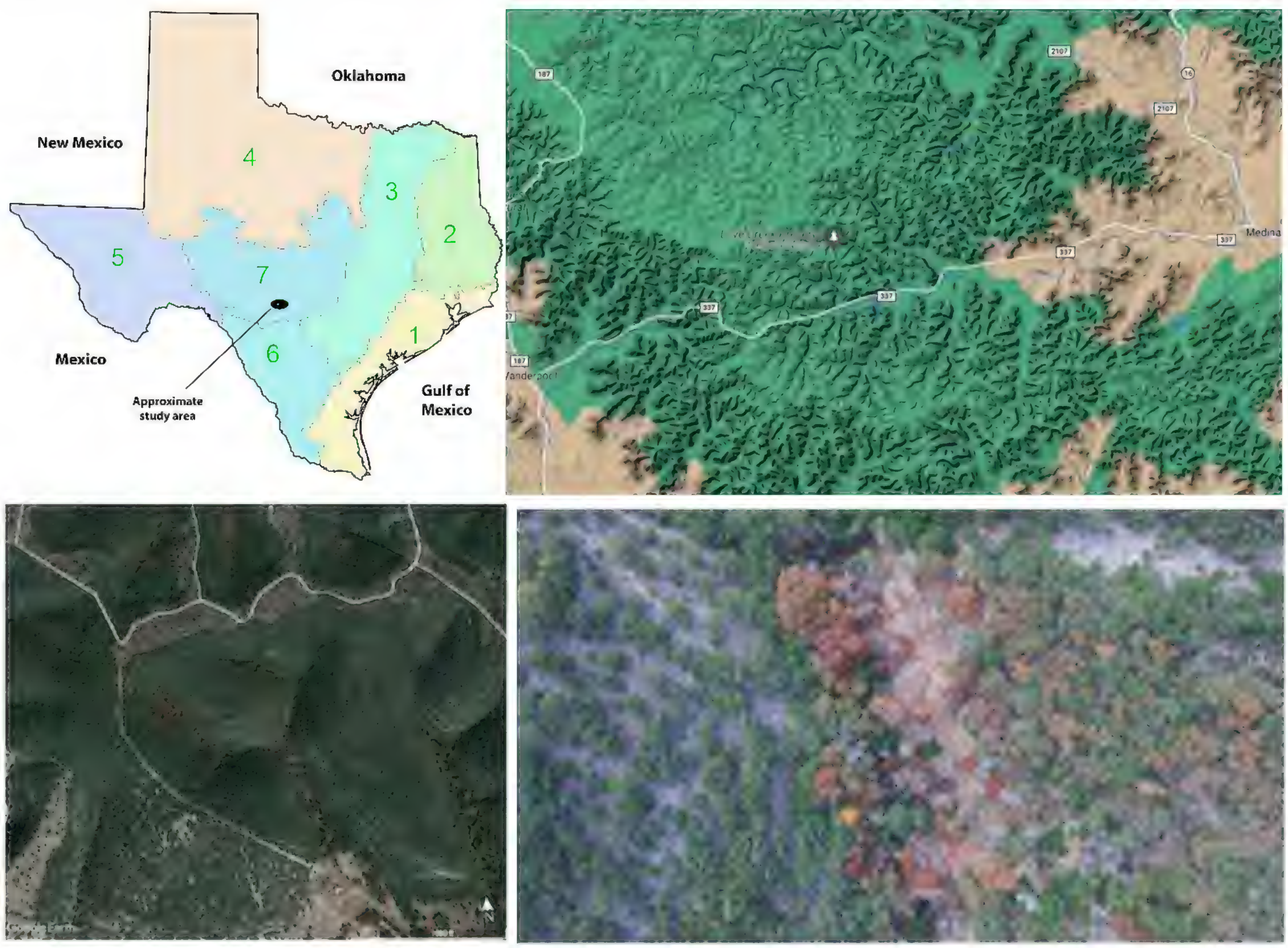

Figure 1. Top left, Texas in the southcentral United States, north of Mexico with The Gulf of Mexico to the southeast. Black oval is the approximate location of the study area in the Edwards plateau region (area number 7). Top right is an expansion of the study area from the previous photo showing general topography. Bottom left, Google aerial imagery taken when bigtooth maple leaf color was most distinct and was used to first identify the deciduous communities. Bottom right, drone image of a deciduous woodland done while flying a DJI Inspire quadcopter.

The elevation of the study area is 484-614 m above mean sea level, and canyon bottom deciduous communities have deep calcareous silty clay soil (Mollisols over limestone bedrock, USDA NRCS 2017). The mean annual temperature is approximately 18.3°C, ranging from near 0.7°C in January to 34.1°C in August, and is highly variable. Mean annual precipitation is 72.4 cm/year with very little in July and August and highly variable, with May and September being wettest (NOAA 2018).

Imagery

At ground level, finding the deciduous communities in the juniper-live oak woodlands is difficult because of the small area covered by the deciduous communities and the rough terrain where they occur. However, the deciduous communities were easily identified from the air by the change of leaf color in the fall (Van Auken and Taylor 2017). We used google aerial imagery taken when bigtooth maple leaf color was greatest to identify and locate the deciduous communities (Fig. 1). We used drone flights and photography to identify the most accessible and largest deciduous communities. We conducted the drone survey when we could easily distinguish the deciduous species color from the juniper and oak. We completed the photography using a DJI Inspire quadcopter at an altitude of 100 m above ground level from the point of liftoff. This allowed orthoimagery coverage of each canyon where the deciduous communities occurred. Cloud cover was high, reducing shadow casts and image stitching errors. We set the camera ISO and shutter speed to auto to adjust based on conditions. We uploaded the captured imagery to Drone Deploy for stitching and then exported it as a georeferenced TIFF image. We then imported the TIFF to ArcGIS desktop software. Using the canopy color as a guide, we outlined the deciduous communities to create polygons, and we calculated the area using the ArcGIS measurement tools. We measured the ground sample areas, summed to get the actual total deciduous community area in hectares (ha), and we multiplied by the specific plant density in plants/ha to estimate the number of plants of each species in the canyon deciduous woodland communities studied (Van Auken and Taylor 2017).

Community Characteristics

We estimated the area of each deciduous community based on a drone survey. We used the mean density of the eight deciduous communities to calculate the density of each overstory and understory species in the canyon deciduous communities. Field conditions and site accessibility allowed ground surveying the deciduous woodlands containing the bigtooth maple woody plant population using the quadrat method (Van Auken et al. 2005). The number of 25 m^2 quadrats varied in each of the communities due to site size, variability, and topography. We determined adequate sampling using stabilization curves (not presented). We also determined relative occurrence (presence):

$$\%\,Occurrence = \left(\frac{species\ found\ x\ number\ of\ communities}{total\ number\ of\ communities}\right) x\ 100$$

We sampled 356, 25 m^2 quadrats (0.885 ha) in the overstory deciduous communities and an area of 0.178 ha of the understory (5, 1 m^2 sub-quadrats in each of the 25 m^2 quadrats to count woody plants, one in each corner and one near the center). We used Correll and Johnston (1979) and USDA (2020) to identify the individuals. We counted and classified overstory as plants greater than 137 cm in height and 3 cm basal diameter. We classified woody plants less than 137 cm in height and/or 3 cm basal diameter as juveniles. We identified and calculated density, relative density, basal area, and relative basal area for each overstory species; we identified and calculated density for the understory species within each community (Van Auken et al. 2017).

RESULTS

Figure 2 shows some of the general community characteristics. We found sixteen woody species in the overstory of these communities with a mean of 7 species/community and a range of 5-12 species/community. Total density of overstory species in the communities examined ranged from 153 plants/ha to 1,024 plants/ha with a mean of 559 ± 599 plants/ha. Total understory density of juvenile woody plants ranged from 3,710 plants/ha to a high of 17,025 plants/ha with a mean of 7,963 ± 9,125 plants/ha. Total basal area of overstory species ranged from 27.1 m^2/ha to 44.2 m^2/ha with a mean of 33.8 ± 4.8 m^2/ha. We found 30 woody species in the understories of the communities. The mean number of understory species was 15, with a range of 12 - 21 species (Fig. 2).

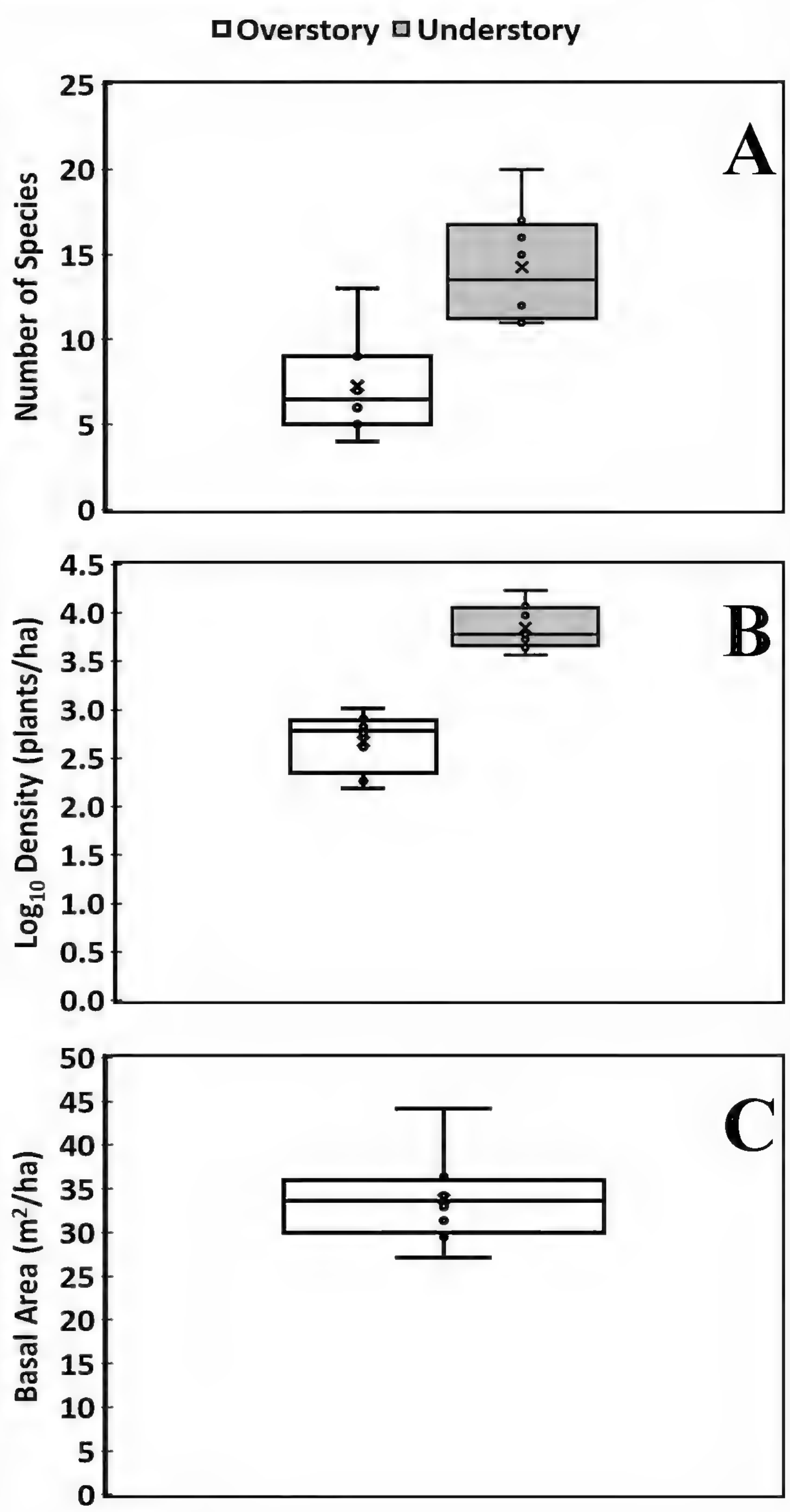

Figure 2. A comparison of the distributions of A) number of woody species and B) density ($\log_{10}$) for overstory(white) and understory(shaded) vegetation, and for C) the basal area of the overstory species. The x in the box represents the mean, the box extends from the 25th to the 75th quantile, the horizontal line within the box is the median, and the "whiskers" are 1.5 times the interquartile range. The mean number of overstory species is 7 ± 3 and 16 ± 3 are in the understory. The mean total density of the overstory is 559 ± 599 plants/ha and the understory is 7,963 ± 4, 563 plants/ha. The mean overstory total basal area of all woody plants is 33.8 ± 4.8 m^2/ha.

In the overstory, we found Ashe juniper (*J. ashei*) and bigtooth maple *(A. grandidentatum*) in every community sampled (100% occurrence, Table 1). Three species of oaks (*Quercus laceyi, muehlenbergii, and buckleyi*) were the next most common species (50-63% occurrence). Texas black walnut (*Juglans major*) also had an occurrence of 63%, but other species were at 50% or less (Table 1). Ashe juniper and bigtooth maple had the highest mean density at 221 ± 179 and 169 ± 73 plants/ha, respectively, out of a total mean density of 559 plants/ha (Table 1). Their mean relative density was 40 and 30%, respectively. Bigtooth maple had the highest basal diameter (9.6 ± 4.7 m^2/ha) and accounted for the largest relative basal area of 43%. Chinkapin oak and Lacey oak also had high basal areas of 6.1 ± 6.1 and 4.4 ± 7.4 m^2/ha (25 and 18% relative basal area), respectively. Ashe junipers were smaller individuals with a mean basal area of 1.3 ± 1.8 m^2/ha (relative basal area of 5%; Table 1).

We found four understory species in all of the communities examined (occurrence = 100%) including sugar hackberry (*C. laevigata*), Texas red oak (*Q. buckleyi*), Ashe juniper (*J. ashei*), and Texas persimmon (*Diospyros texana*) (Table 2). Eight species had 75-88% occurrence including bigtooth maple (Table 2).

The mean density of the species with 100% occurrence ranged from 602 to 1201 plants/ha (Table 2). The species with 75-88% occurrence had mean density values from 138 to 926 plants/ha (Table 2). We found other species in at least one community with a density as low as four plants/ha.

Table 1. Woodland overstory species (scientific and common names) as well as percent occurrence, mean density (plants/ha; 1 ± standard deviation), relative density, mean basal area (m^2/ha; 1 ± standard deviation), and relative basal area. Species are ranked from high to low (top to bottom) based on mean density.

OVERSTORY						
Scientific name	**Common Name**	**% Occur.**	**Density (plants/ha)**	**Relative Density (%)**	**Basal Area m^2/ha)**	**Relative Basal Area (%)**
Juniperus ashei	Ashe juniper	100	221±179	40	1.3 ± 1.8	5
Acer grandidentatum	Bigtooth maple	100	169 ± 73	30	9.6 ± 4.7	43
Quercus laceyi	Lacey oak	63	41 ± 60	7	4.4 ± 7.4	18
Quercus muehlenbergii	Chinkapin oak	50	26 ± 28	5	6.1 ± 6.1	25
Sophora secundiflora	Mt. laurel	38	23 ± 44	4	< 0.1	< 1
Diospyros texana	Texas persimmon	50	20 ± 29	4	< 0.1	< 1
Vitis arizonica	Arizona grape	38	14 ± 25	3	< 0.1	< 1
Juglans major	Tx. black walnut	63	10 ± 10	2	0.4 ± 0.6	2
Fraxinus albicans	Texas ash	50	9 ± 10	2	0.9 ± 0.9	4
Prunus serotina	Black cherry	25	6 ± 12	1	0.7 ± 1.2	3
Ungnadia speciosa	Mex. Buckeye	25	5 ± 9	1	0.1 ± 0.3	< 1
Quercus buckleyi	Texas red oak	50	5 ± 6	1	0.3 ± 0.5	1
Sideroxylon lanuginosum	Gum bumelia	25	5 ± 11	1	< 0.1	< 1
Aesculus pavia	Red buckeye	13	2 ± 6	< 1	< 0.1	< 1
Celtis laevigata	Sugar hackberry	13	1 ± 2	< 1	< 0.1	< 1
Tilia caroliniana	Carolina basswood	13	1 ± 3	< 1	0.2 ± 0.6	1
Total			559	99	24.5	98

DISCUSSION

This descriptive study of deciduous woodlands in the Edwards Plateau in central Texas indicates a relatively diverse community for this area. These eight deciduous woodlands are ecologically similar to deciduous woodlands described in other areas of the Edwards Plateau (Van Auken et al. 1981; Gehlbach 1988), and similar to the communities reported in the upper canyons of this area (Palmer 1920). Differences between communities included 16 woody species (trees or shrubs) found in the current study while 19 were reported in the previous study (Van Auken et al. 1981). Chinkapin oak (*Q. muehlenbergii*), bigtooth maple (*A. grandidentatum*), gum bumelia (*Sideroxylon lanuginosum*), and Carolina basswood (*Tilia caroliniana*) were not found in the previous study. Blue sage (*Salvia ballotiflora,* shrub) was not found in the current study. Other notable differences in plant species between the two studies included lower density of Texas persimmon (*Diospyros texana)* in the current study when compared to the previous study; and a lower density of Lacey oak (*Q. laceyi*) and Texas red oak (*Q. buckleyi,* formerly *Q. texana*) in the present study.

Over all woody plant density was lower in the current study when compared to the earlier study (Van Auken et al. 1981). There may be several reasons which would explain these differences. The current study focused on communities in canyons which are at a lower elevation and more shaded than the north facing slopes of the previous study, which may be as much as 150 meters higher. Further, the communities in the first study were 40-50 km further southeast (closer to the southern edge of the physiographic Edwards Plateau region), were brushy, and probably drier. All studies were on private property and as ownership changed land management changed (Carpenter and Brandimarte 2014). Methodology was slightly different between the two studies, with multi-stem species (red buckeye; *Aesculus pavia*) counted per stem (first study) rather than per clump. The deciduous woodland communities in the current study were very open, with few large understory shrubs. Understory density was high in most of the current communities studied, but the woody plants were mostly less than 10 cm tall. In the understory of the current study there were 30 woody species including 16 juvenile tree species, 10 shrubs, and 4 woody vines (Table 2). The previous study did not measure the understory plants.

Table 2. Understory woody species (scientific and common names) as well as percent occurrence, mean density (plants/ha; 1 ± standard deviation), and relative density. Species are ranked from high to low (top to bottom) based on mean density.

UNDERSTORY					
Scientific name	**Common name**	**% Occurrence**	**Mean density**	**SD**	**% Density**
Celtis laevigata	Sugar hackberry	100	1201 ±	2450	15
Quercus buckleyi	Texas red oak	100	1059 ±	430	13
Quercus laceyi	Lacey oak	88	926 ±	941	12
Juniperus ashei	Ashe juniper	100	667 ±	753	8
Quercus muehlenbergii	Chinkapin oak	75	658 ±	704	8
Acer grandidentatum	Bigtooth maple	88	642 ±	700	8
Diospyros texana	Texas Persimmon	100	602 ±	445	8
Parthenocissus quinquefolia	Virginia creeper	88	386 ±	545	5
Sideroxylon lanuginosa	Gum bumelia	63	273 ±	519	3
Vitis arizonica	Arizona grape	75	257 ±	307	3
Smilax bona-nox	Saw greenbriar	88	249 ±	234	3
Sophora secundiflora	Mountain laurel	50	241 ±	370	3
Ungnadia speciosa	Mexican buckeye	50	204 ±	412	3
Fraxinus albicans	Texas ash	88	158 ±	188	2
Prunus serotina	Black cherry	88	138 ±	106	2
Ilex decidua	Possumhaw holly	13	99 ±	279	1
Juglans microcarpa	Arizona walnut	63	46 ±	70	1
Ulmus crassifolia	Cedar Elm	13	37 ±	104	1
Mahonia trifoliolata	Agarita	25	26 ±	57	<1
Rhamnus caroliniana	Carolina basswood	25	24 ±	50	<1
Toxicodendron radicans	Poison Ivy	25	12 ±	30	<1
Ptelea trifoliata	Hop tree	13	11 ±	31	<1
Tilia caroliniana	Carolina buckthorn	13	10 ±	28	<1
Styphnolobium affine	Eve's necklace	13	7 ±	19	<1
Ageratina havanensis	Shrubby boneset	13	7 ±	19	<1
Cercis canadensis	Redbud	25	6 ±	11	<1
Yucca rupicola	Twisted-leaf yucca	13	6 ±	16	<1
Baccharis neglecta	Roosevelt weed	13	6 ±	16	<1
Rhus virens	Evergreen sumac	13	4 ±	10	<1
Styrax platanifolius	Sycamore leaf snowbells	13	4 ±	10	<1
Total			**7963**		**99**

We were interested in describing the composition and structure of these communities, which is a gap in knowledge. There are reports suggesting population declines of many deciduous species in the Edwards Plateau possibly caused by browsing by white-tailed deer (*Odocoileus virginianus* Zimmerman) (McCorkle 2007; Boerne Chapter of the Native Plant Society of Texas 2015; Nelson-Dickerson and Van Auken 2016; Van Auken and Taylor 2021).

The loss of most large vertebrate predators in the Edwards Plateau region of Texas caused populations of white-tailed deer to become the major large herbivores in the area. Estimates suggest white-tailed deer are at or above carrying capacity causing negative impacts on vulnerable plant populations (Fulbright and Ortega-S. 2008; Wolverton et al. 2007). Browsing by white-tailed deer has been suggested as a major factor in recruitment failure in populations of Texas red oak, eastern black cherry and Texas ash (*Q. buckleyi, P. serotina* and *F. albicans*) favoring increased density and biomass of ash juniper (Russell and Fowler 2004; Van Auken 1988). The same seems to be true for bigtooth maple (Nelson Dickinson and Van Auken 2016; Van Auken and Taylor 2021).

Density values presented in the current document represent the mean number of woody plants found in the quadrates measured as plants per hectare. We estimated the total area of the deciduous communities surveyed to be 9.56 ha. Mean density values presented are per hectare and if the plants are equally found through the deciduous communities examined, the actual number of plants of a given species would be expected to be 9.56 times higher because of the total area of the deciduous woodlands. Some comparisons are indicated below but all are in the table (Table 3).

Table 3. Woodland community overstory species (scientific and common names) as well as calculated density (actual density in plants/hectare X measured community area in hectares) and community understory density. Species are ranked from high to low (top to bottom) based on mean overstory density.

Scientific name	Common Name	Estimated whole community overstory density	Estimated whole community understory density
Juniperus ashei	Ashe juniper	2,113	6,176
Acer grandidentatum	Bigtooth maple	1,616	5,945
Quercus laceyi	Lacey oak	392	8,575
Quercus muehlenbergii	Chinkapin oak	249	6,693
Sophora secundiflora	Mt. laurel	220	2,232
Diospyros texana	Texas persimmon	191	5,575
Vitis arizonica	Arizona grape	134	2,380
Juglans major	Texas black walnut	96	426
Fraxinus albicans	Texas ash	86	1,463
Prunus serotina	Black cherry	57	1,278
Ungnadia speciosa	Mex. buckeye	48	1,889
Quercus buckleyi	Texas red oak	48	9,806
Sideroxylon lanuginosum	Gum bumelia	48	2,528
Aesculus pavia	Red buckeye	20	0
Celtis laevigata	Sugar hackberry.	10	11,121
Tilia caroliniana	Carolina basswood	10	93

These whole community density values suggest that there are 11,121 sugar hackberry juveniles in the understory of these deciduous communities and we only found one mature tree/ha in the overstory and estimated 10 in the whole community (Table 3). There were 25,074 *oak* juveniles found in the understory (three species) with 72 overstory plants/ha or 689 trees in the whole community. For Ashe juniper, there were 221 plants/ha (highest mean tree density) and 2,113 expected for the entire deciduous community. In the understory the mean for juniper juveniles was 667 plants/ha, while the estimated number for the deciduous woodland community was 6,176, which was the fourth highest juvenile woody plant.

Bigtooth maple, our main species of interest in these deciduous woodlands, had an overstory mean density of 169 plants/ha. Expanding this density to the area of the entire deciduous woodland indicated 1,616 bigtooth maple trees. Understory bigtooth maple juvenile density was 642 plants/ha or expanded to the deciduous woodland, the density of juveniles would be 5,945 plants. At this density, it would seem that there would be sufficient numbers for adequate recruitment to maintain the adult population. However, there were no saplings reported in a previous study and none in this study (Nelson-Dickerson and Van Auken 2016).

Although many more potential deciduous woodland communities were observed in the satellite imagery, the ability to fly the UA in these areas was limited because of FAA rules. Without accessible roads close enough to the deciduous woodland community, these areas were not flown because the drone could not be seen constantly. Consequently, 26 flights were done over deciduous woodlands detected in the satellite imagery. Of those, 23 produced imagery worthy of further evaluation. Out of the 23 sites, 10 were selected for ground surveys. Based on walking through all ten, two of the ten sites selected did not have bigtooth maple trees and were not quantitatively surveyed. The remaining eight were surveyed, all contained adult bigtooth maples and all but one had juveniles.

The deciduous woodland communities identified and examined in the current study were similar to deciduous woodland communities identified in the past (Van Auken et al. 1981) but had bigtooth maple trees. We found and report a few species that were not previously described from these communities. In spite of examining a large area, the number of individual woody species was relatively small compared to wetter or more tropical areas (Mutke and Barthlott 2005; or see Keddy 2017). We could tell if a specimen was juvenile (non-reproductive) or mature, but not the specific age. In addition, time of loss or age when adults were lost was not obvious. Consequently, additional study will be necessary to understand the stability or lack of stability of these unusual communities.

ACKNOWLEDGEMENTS

Ground surveying the sites was very difficult because of the steep slopes and density of the communities examined. The following were very perseverant and helpful collecting the field data used to describe the plant communities in the current study including Ms. Anne Adams, Ms. Tara Putman, Mr. Gary Fest, Ms. Brenda Fest, Ms. Maria Harrison and Dr. Clark Terrell. Ms. Tabitha Counts helped with graph development and features in JMP. Mr. Jason Gagliardi assisted with some of the JMP statistical programs. Mr. Stuart Foot aided with the figures including the map of Texas and the Google map showing the general study area. Mr. Charles Wu found some obscure literature that was very useful. We thank David D. Diamond, Victoria Makar and Vonnie V. Jackson for reading an earlier version of this paper and they made some very obliging comments and corrections.

LITERATURE CITED

Amos, B. and F. R. Gehlbach. 1988. Edwards Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, TX.

Barbour, M. G. and W. D. Billings. 1988. North American terrestrial vegetation. Cambridge University Press, NY.

Boerne Chapter of the Native Plant Society of Texas. 2015. Maples for Boerne. The Boerne Chapter of NPSOT, < http://npsot.org/wp/boerne/maples-for-boerne/>.

Carpenter, J. and C. Brandimarte. 2014. The Albert and Bessie Kronkosky State Natural Area: A History of Lands and People. Historic Sites and Structures Program, State Parks Division, Texas Parks and Wildlife Department (Available online TPWD as a Draft or james.rice@tpwd.texas.gov).

Collins, S. L. and L. L. Wallace. 1990. Fire in North American tallgrass prairies. University of Oklahoma Press, Norman, OK.

Correll, D. S. and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, TX.

Elliott, L. F., D. D. Diamond, C. D.True, C. F. Blodgett, D. Pursell, D. German and A. Treuer-Kuehn. 2014. Ecological mapping systems of Texas: summary report. *Austin, Texas: Texas Parks and Wildlife Department.* https://tpwd.texas.gov/gis/programs/landscape-ecology/supporting-documents/final-summary-report/view

Fulbright, T. E. and J. A. Ortega-S. 2008. White-tailed Deer Habitat: Ecology and Management on Rangelands. Texas A & M University Press, College Station.

Gehlbach, F. R. 1988. Forests and woodlands of the northeastern Balcones Escarpment. *in*: Edward's Plateau vegetation: plant ecological studies in central Texas. B. B. Amos and F. R. Gehlbach, eds., Baylor University Press, Waco, TX.

Gould, F. W. 1969. Texas plants-a checklist and ecological summary. Texas Agriculture Experiment Station Bulletin, MP-583.

Hill, R. T. 1892. Notes on the Texas-New Mexico region. Bull. Geol. Soc. Amer. 3:85-100.

Inglis, J. M. 1964. A history of vegetation on the Rio Grande plain. Texas Parks and Wildlife Department. Bulletin No. 45.

Keddy, P. A. 2017. Plant ecology: origins, processes, consequences. Cambridge University Press, New York, NY.

Mutke, J. and W. Barthlott. 2005. Patterns or vascular plant diversity at continental to global scales. Biol. Skrifer. 55:521-531.

McCorkle, R. 2007. September 2007 Park of the Month: Lost Maples State Natural Area. http://www.tpwd.state.tx.us/spdest/findadest/parks/park_of_the_month/archive/2007/07 09.phtml

Nelson-Dickerson, T. L. and O. W. Van Auken. 2016. Survival, Growth and Recruitment of Bigtooth Maple (*Acer grandidentatum*) in Central Texas Relict Communities. Nat. Areas J. 36:174-180. https://doi.org/10.3375/043.036.0209

NOAA. 2018. National Oceanic and Atmospheric Administration. National Climatic Data Center, Asheville, NC. https://www.noaa.gov/. (Accessed July 14, 2018).

Palmer, E. J. 1920. The canyon flora of the Edwards Plateau of Texas. J. Arnold Arbor. 1:233-239.

Poole, J. M., W. R, Carr, D. M, Price and J. R. Singhurst. 2007. Rare Plants of Texas. Texas A&M Nature Guides. Texas Parks and Wildlife. Everbest Printing, Louisville, KY.

Russell, F. L. and N. L. Fowler. 2004. Effects of white-tailed deer on the population dynamics of acorns, seedlings and small saplings of *Quercus buckleyi*. Plant Ecol. 173:59-72.

Ruzicka, K. J., J. W. Groninger and J. J. Zaczek. 2010. Deer browsing, forest edge effects, and vegetation dynamics following bottomland forest restoration. Rest. Ecol. 18:702-710.

Sims, P. L. 1988. Grasslands. *in* North American Terrestrial Vegetation. M. G. Barbour and W. D. Billings, eds., Cambridge University Press, NY.

Strole, T. A. and R. C. Anderson. 1992. White-tailed deer browsing - species preferences and implications for Central Illinois forests. Nat. Areas J. 12:139-144.

Tharp, B. C. 1939. The vegetation of Texas. Anson Jones Press, Houston.

USDA NRCS. 2017. Web Soil Surveys, Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, Washington, DC, (National Resources Conservation Service, 2017). (Accessed 2017).

USDA. 2020. Plants Database, USDA Natural Resources Conservation Service. http://plants.usda.gov/java/profile?symbol

Van Auken, O.W. 1988. Woody vegetation of the southeastern escarpment and Plateau. *in*: B. B. Amos and F. R. Gehlbach, eds., Edward's Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, TX.

Van Auken, O. W. 2000. Shrub invasions of North American semiarid grasslands. Ann. Rev. Ecol. Syst. 31:197-215.

Van Auken, O. W., A. L. Ford and A. Stein. 1979. A comparison of some woody upland and riparian plant communities of the southern Edwards Plateau. Southwest Nat. 24:165-175.

Van Auken, O. W., A. L. Ford and J. L. Allen. 1981. An ecological comparison of upland deciduous and evergreen forests of central Texas. Amer. J. Bot. 68:1249-1256.

Van Auken, O. W., J. K. Bush and S. A. Elliott. 2005. Ecology-laboratory manual. Pearson Custom Publishing, Boston, MA.

Van Auken, O. W. and D. L. Taylor. 2017. Using a drone (UAV) to determine the *Acer grandidentatum* (bigtooth maple) density in a relic, isolated community. Phytologia 99:208-220.

Van Auken, O. W., D. L. Taylor, C. Shen and J. K. Bush. 2017. Structure of isolated *Acer grandidentatum* (bigtooth maple) Communities and Potential Population Changes. Amer. J. Plant Sci. 98:232-240.

Van Auken, O. W. and A. L. Ford. 2017. Flood caused changes to the upper Guadalupe River riparian forest of central Texas. Phytologia 99:226-237.

Van Auken, O. W. 2018. Ecology of plant communities of south-central Texas. Scientific research Publishing.

Van Auken, O. W. and D. L. Taylor. 2021. Survival of juvenile *Acer grandidentatum* Nutt. (Bigtooth Maple, Aceraceae) in central Texas. Amer. J. Plant Sci. 11: 413-425.

Wolverton. S., J. H. Kennedy and J. D. Cornelius. 2007. A paleozoological perspective on whitetailed deer (*Odocoileus virginianus texana*) population density and body size in central Texas. Envir. Manag. 39:545-552.